EE 500 GRADUATE COLLOQUIUM

Spring 2014

You are cordially invited to

"The Life and Times of the Great Inventor, Nikola Tesla"

(A Repeat of the 150th Tesla Anniversary Presentation by Prof. James Breakall and Mr. David Blood in 2006)

By

Dr. James Breakall

Department of Electrical Engineering

Pennsylvania State University

Date: February 27, 2014

Time: 4:00 pm

Location: 160 Willard Bldg.

Abstract

To celebrate the 150th anniversary of Nikola Tesla in 2006, Prof. Breakall and Mr. David Blood presented a very memorable and popular public seminar and demonstration for the EE Department at Penn State. At this event, the life and times of Nikola Tesla were discussed and several Tesla coils were displayed and utilized for various live demos with audience participation. This seminar was videotaped and Prof. Breakall will play this DVD and slide presentation at this Spring, 2014, EE Graduate Colloquium.

Nikola Tesla is clearly one of the greatest scientists and inventors in the history of the technological development of humankind. His patents and theoretical work created conditions for the electrification of the world by his system of poly-phase alternating current, the system that is still presently used all over the world. His work in the field of high-frequency currents and wireless transmission of electromagnetic waves made the development of radio and telecommunications possible. Tesla's research also helped towards the invention of radar, and in many ways brought about the development of lighting. Tesla always arrived at an invention in a rather unusual way. He first would work out the whole idea of the way a device should work to the smallest detail in his mind, and then he would "see" how it works, and then he would proceed to prove it theoretically, sketch it, and finally make the device itself that would then work without any problem. Working things out in his mind and not on paper would insure that his inventions would be protected. Nikola Tesla was born in 1856 in Smiljan, a small village near Gospić, Croatia.

At the end of the 19th century in Colorado Springs, CO, Tesla performed various experiments with very high voltages and high-frequency currents. In the laboratory he managed to produce artificial lightning with the voltage discharge of many millions of volts and the length of the lightning of up to 40 meters. Nikola Tesla filed a total of some 300 patents all over the world. He received honorary doctorates for his work at numerous universities including Columbia University, Yale University, University de Poitiers, Polytechnic Institutes of Graz, Vienna and Bucharest, Universities of Belgrade, Brno, Grenoble, Paris, Prague, Sofia, and Zagreb. Nikola Tesla never married, he left no direct heirs, and he also suffered from many phobias. He was fascinated by cleanliness and the number three. At the end of his life he liked to keep company with pigeons.

Besides his native language, Tesla fluently spoke English, French, German, Italian, Czech and Hungarian. He died in 1943 in a hotel in New York. To honor the great inventor, the unit for magnetic induction in the SI system was named Tesla in 1960. In 1975, the Institute of Electrical and Electronics Engineers (IEEE) established the Nikola Tesla Award that is given to deserving individuals in the field of electro-energetics. As commendation for Tesla's achievements, a crater on the Moon carries his name.

Biography

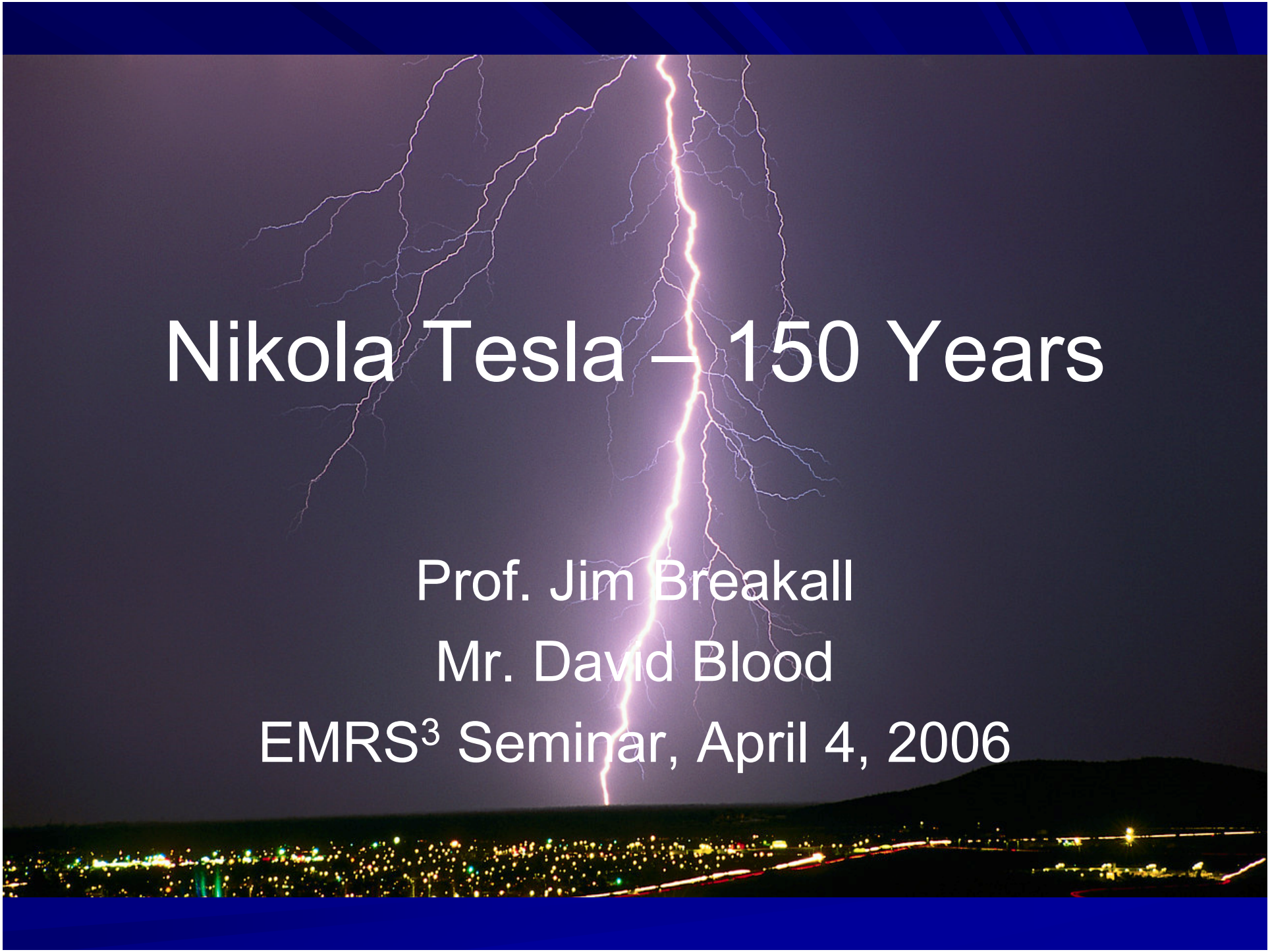
James K. Breakall received B.S. and M.S. degrees in Electrical Engineering from Penn State University and a Ph.D. in Electrical Engineering and Applied Physics from Case Western Reserve University, Cleveland, OH, and has over 40 years of experience in numerical electromagnetics and antennas. He was a Project Engineer at the Lawrence Livermore National Laboratory (LLNL), Livermore, CA, and an Associate Professor at the Naval Postgraduate School (NPGS), Monterey, CA. Presently he is a Full Professor of Electrical Engineering at Penn State. Dr. Breakall began his career in both theoretical and experimental research as a graduate student at the Arecibo Observatory in Puerto Rico working on antenna analysis and radar probing of the ionosphere. At LLNL, he and his group worked on the development of the Numerical Electromagnetics Code (NEC), the first sophisticated antenna modeling program. At Penn State Dr. Breakall was engaged in a project to design and construct the world's most powerful and sophisticated ionospheric modification facility, HAARP, leading him to design a unique antenna invention, the Three Dimensional Frequency Independent Phased Array (3D FIPA), which was awarded an U. S. patent.

Dr. Breakall has also led work at Penn State on several programs with the Navy to study high frequency (HF) antenna sitting in irregular terrain with helicopter measurements, a propagation project named the Polar Equatorial Near-Vertical Incidence Experiment (PENEX), a project named TACAMO for VLF communication to submarines from trailing aircraft 5 mile long wires, a UHF Electronically Scanned Array (UESA) for the antenna design on the E-2C Hawkeye radar dome aircraft, and most recently a National Science Foundation (NSF) project for the design of a new high power HF feed at the Arecibo Observatory 1000 foot dish antenna.

Dr. Breakall has been actively involved in the Applied Computational Electromagnetics Society (ACES) of which he helped found in 1985 at LLNL and has been elected to two 3 year terms on the Board of Directors by the more than 600 worldwide members. He has graduated numerous Ph.D., M.S., EE Honors and Math Honors students at Penn State and is currently the thesis advisor for Ph.D., M.S., and E.E. honors students. Dr. Breakall is also a member of the IEEE Antennas and Propagation Society, IEEE Broadcast Technology Society, Eta Kappa Nu, International Union of Radio Science Commission B, IEEE Wave Propagation and Standards Committee, has been an Associate Editor for the Radio Science journal, and served as an Arecibo Observatory Users and Scientific Advising Committee Member. He was won many prestigious awards and honors, including the Applied Computational Electromagnetics Society Mainstay Award, the Outstanding Research Award from the Penn State College of Engineering, and has been named the Charles H. Fetter Fellow in Electrical Engineering. He has also advised Nittany Scientific, Inc., on several Penn State licensed projects involving new antenna software and hardware sold commercially. He was also on

the Board of Directors for a company, Star-H, that is involved in antenna design and manufacturing. With Star-H, he has also received a patent on his invention of a low-profile AM broadcast radio station antenna. He finished a sabbatical leave in 2011-2012 at the Army CERDEC, Aberdeen Proving Ground, MD and Arecibo Observatory, Puerto Rico. He has also been employed as a Summer contractor to the Army in Aberdeen, MD for the past 3 Summers. He has spent this past year at the Army in Aberdeen, MD engaged in off-campus research from Penn State.

You can reach him at 225 Electrical Engineering East, Penn State University, University Park, PA 16802 or at ***jimb@psu.edu****.*



Nikola Tesla – 150 Years

Prof. Jim Breakall

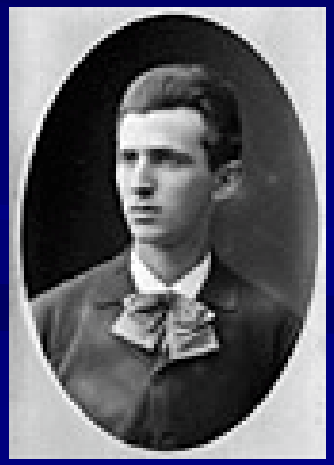
Mr. David Blood

EMRS^3 Seminar, April 4, 2006

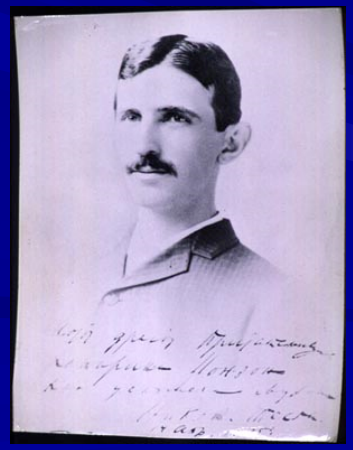
History

- Nikola Tesla - born a subject of the Austro-Hungarian Empire in 1856 in a mountainous area of the Balkan Peninsula known as Lika.

- At age 23



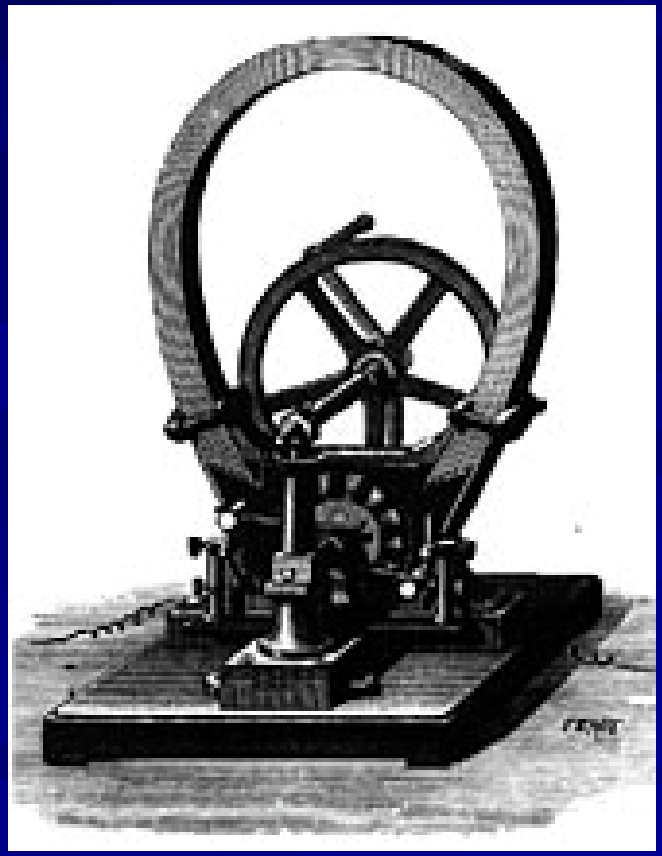
At age 29



History

- An early sign of his genius, he was able to perform integral calculus in his mind, prompting his teachers to think he was cheating.
- Attended the renowned Austrian Polytechnic School at Graz to study engineering.
- One day a physics teacher showed Tesla's class a new Gramme dynamo that—by employing direct current—could be used as both a motor and a generator.
- Tesla suggested it might be possible to do away with a set of inefficient sparking connections known as commutators.
- His professor said this would be like building a perpetual motion machine!
- For the next several years the challenge obsessed Tesla, who instinctively knew that the solution lay in electric currents that alternated.

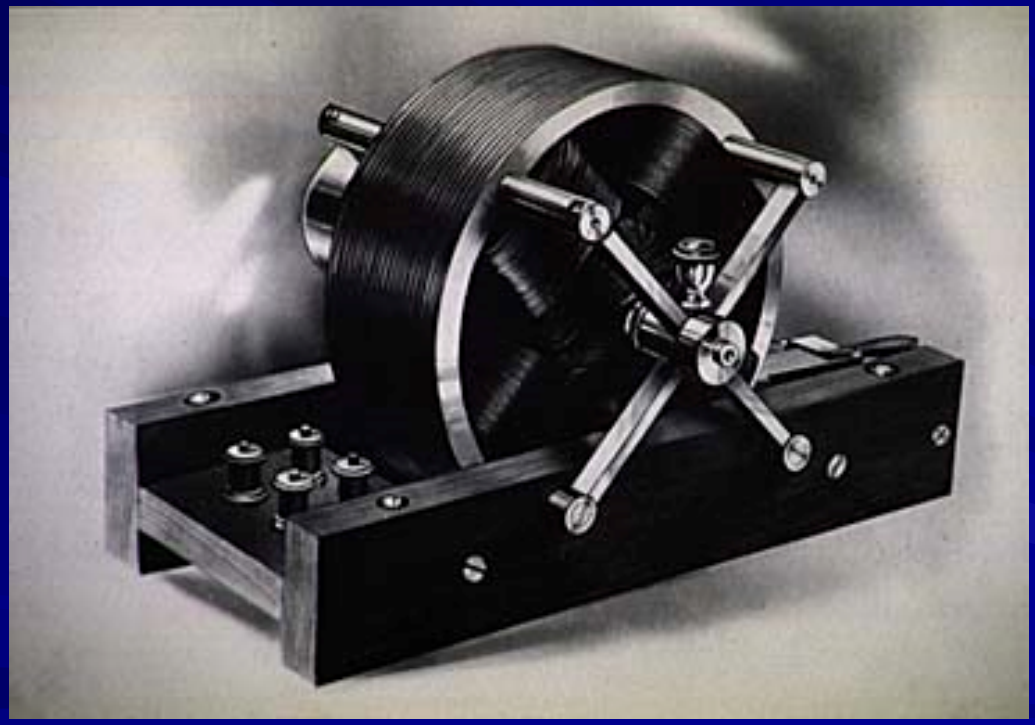
Gramme dynamo, 1877 (Courtesy Smithsonian Institution)



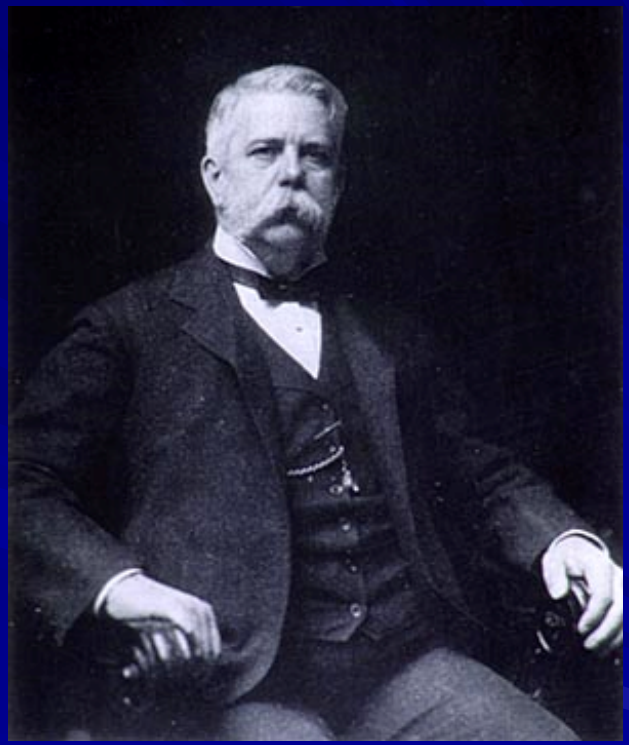
History

- It wasn't until age twenty-four, when Tesla was living in Budapest and working for the Central Telephone Exchange, that the answer came to him:
- “One afternoon, which is ever present in my recollection, I was enjoying a walk with my friend in the city park and reciting poetry. At that age I knew entire books by heart, word for word. One of these was Goethe's *Faust.* As I uttered these inspiring words the idea came like a flash of lightning and in an instant the truth was revealed. I drew with a stick on the sand the diagram shown six years later in my address before the American Institute of Electrical Engineers.”
- This was the invention of the induction motor, a technological advance that would soon change the world.

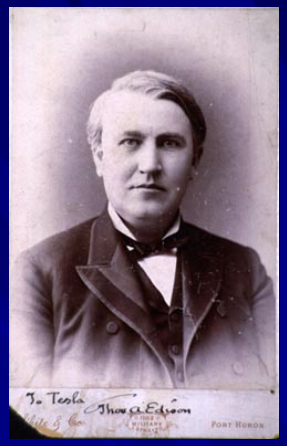
One of the two two-phase induction motors demonstrated by Tesla in his historic lecture of May, 16, 1888, before the American Institute of Electrical Engineers at Columbia University. The motor developed 1/2 horsepower and showed that brushes and commutators could be eliminated.



Early Tesla induction motor manufactured by Westinghouse Electric Company (Photo of George Westinghouse shown in 1906)



Tesla and Edison



- It was clear that in order to realize his idea, he would have to meet the greatest electrical engineer in the world—Thomas Alva Edison.
- Edison's incandescent lamp had created an astonishing demand for electric power with his DC power station on Pearl Street in lower Manhattan.
- Edison knew little of alternating current and did not care to learn more about it. In short, AC power sounded like competition to Edison.
- Edison immediately hired him to make improvements in his DC generation plants.
- Tesla claimed that Edison promised him $50,000 if he succeeded, perhaps thinking it an impossible undertaking.

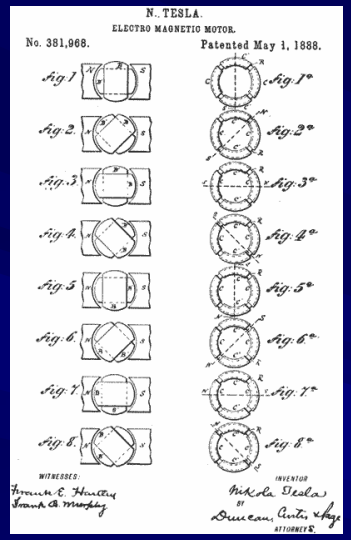
History – Tesla and Edison

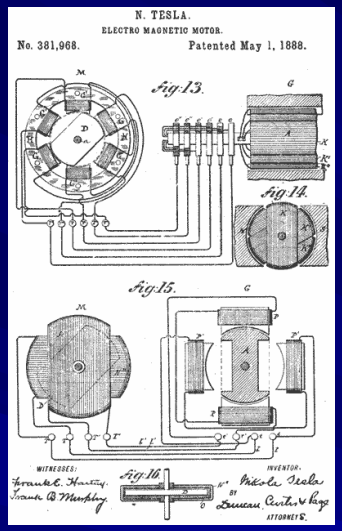
- Both Tesla and Edison shared a common trait of genius in that neither of them seemed to need much sleep.
- Tesla claimed that his working hours at the Edison Machine Works were 10:30 a.m. till 5 a.m. the next day.
- Even into old age Tesla said he only slept two or three hours a night.
- Tesla relied on moments of inspiration, perceiving the invention in his brain in precise detail before moving to the construction stage.
- Edison was a trial and error man who described invention as five percent inspiration and 95 percent perspiration.
- When Tesla asked to be paid for improvements made into Edison's system, however, Edison seemed astonished. He explained that the offer of $50,000 had been made in jest.
- Shocked and disgusted, Tesla immediately resigned.

Tesla’s Luck Changes

- Mr. A.K. Brown of the Western Union Company, agreed to invest in Tesla's idea for an AC motor.
- Tesla quickly developed all the components for the system of AC power generation and transmission that is used universally throughout the world today.
- "The motors I build there," said Tesla, "were exactly as I imagined them. I made no attempt to improve the design, but merely reproduced the pictures as they appeared to my vision and the operation was always as I expected."
- The battle to produce his motor was over.

In November and December of 1887, Tesla filed for seven U.S. patents in the field of polyphase AC motors and power transmission.


N. TESLA.
ELECTRO MAGNETIC MOTOR.
No. 381,968. Patented May 1, 1888.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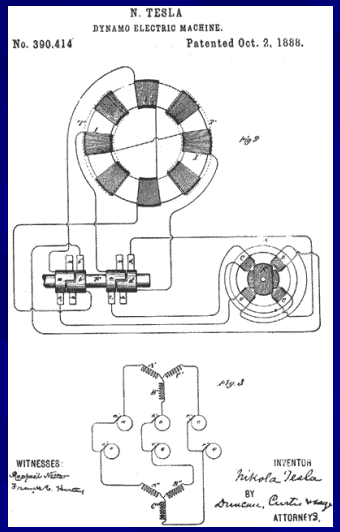
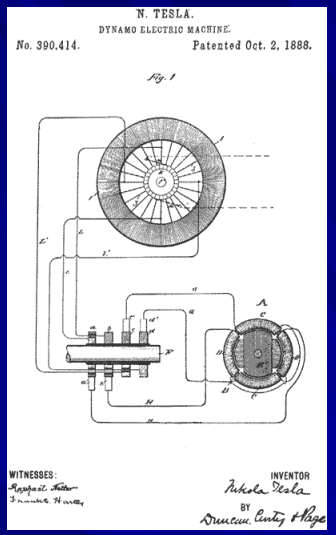

N. TESLA
DYNAMO ELECTRIC MACHINE.
No. 390,414 Patented Oct. 2, 1888.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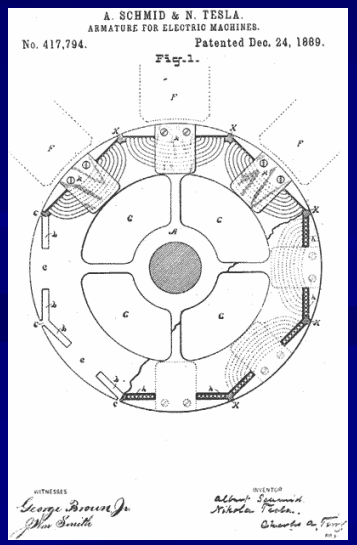
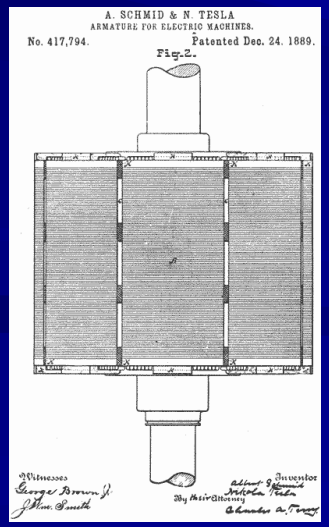

A. SCHMID & N. TESLA.
ARMATURE FOR ELECTRIC MACHINES.
No. 417,794. Patented Dec. 24, 1889.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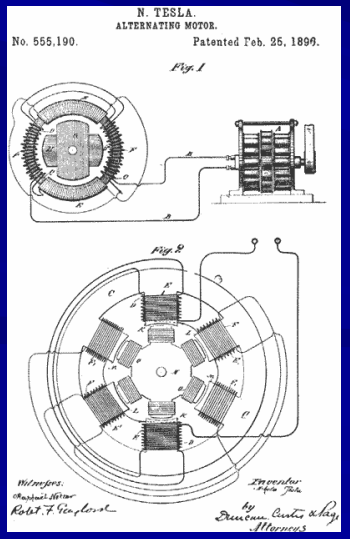

N. TESLA.
ALTERNATING MOTOR.
No. 555,190. Patented Feb. 25, 1896.

Tesla’s AC Patents

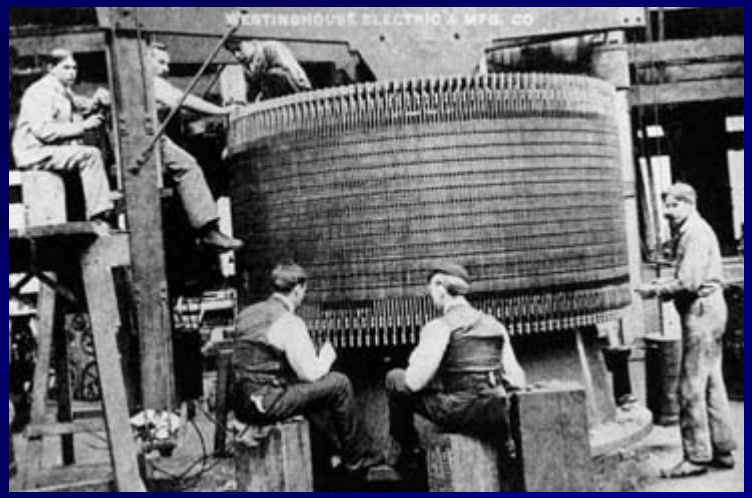
- These comprised a complete system of generators, transformers, transmission lines, motors and lighting.
- So original were the ideas that they were issued without a successful challenge, and would turn out to be the most valuable patents since the telephone.
- With the breakthrough provided by Tesla's patents, a full-scale industrial war erupted.
- At stake, in effect, was the future of industrial development in the United States, and whether Westinghouse's alternating current or Edison's direct current would be the chosen technology.

Battle of DC vs. AC

- Westinghouse recalled: “I remember Tom [Edison] telling them that direct current was like a river flowing peacefully to the sea, while alternating current was like a torrent rushing violently over a precipice. Imagine that! Why they even had a professor named Harold Brown who went around talking to audiences... and electrocuting dogs and old horses right on stage, to show how dangerous alternating current was.”
- Meanwhile, a murderer was about to be executed in the first electric chair at New York's Auburn State Prison.
- Professor Brown had succeeded in illegally purchasing a used Westinghouse generator in order to demonstrate once and for all the extreme danger of alternating current.
- Quotes of "an awful spectacle, far worse than hanging." The technique was later dubbed "Westinghousing."

"Court of Honor" at the Columbian Exposition in Chicago, 1893. The age of light that Tesla did so much to bring about was exemplified in this scene. At nightfall, "stopper" (or Sawyer-Man) lamps by Westinghouse provided the most spectacular lighting display the world had ever seen.

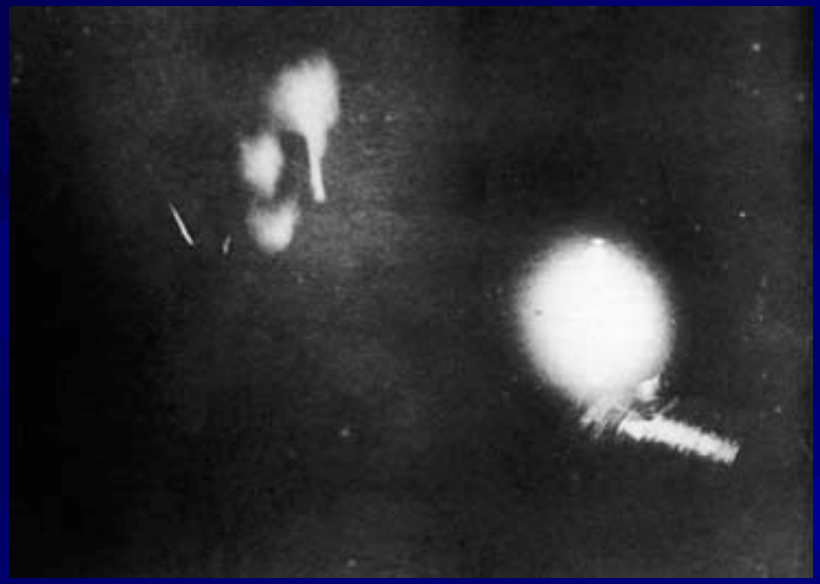
Niagara Falls



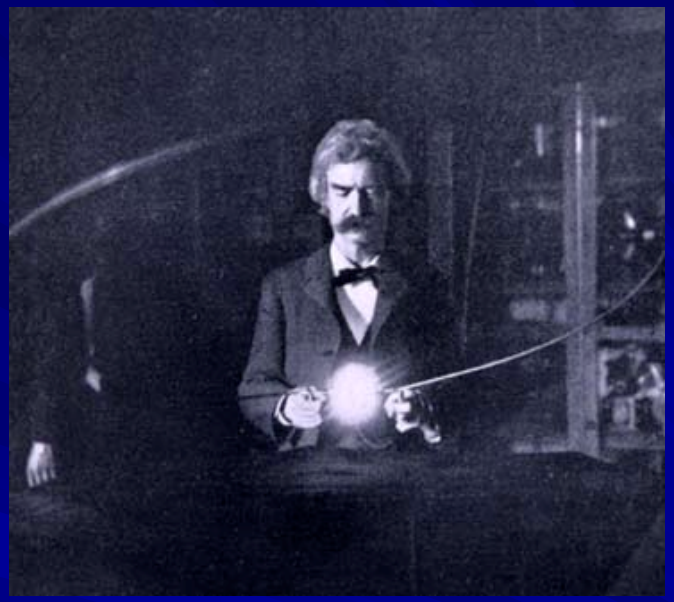
A Niagara generator under construction at Westinghouse in Pittsburgh in 1894.

Interior of Edward Dean Adams power station at Niagara, with ten 5,000 horsepower Tesla/Westinghouse AC generators—the culmination of Tesla's dream. (Courtesy Smithsonian Institution)

Tesla's lifelong obsession—the wireless transmission of energy.

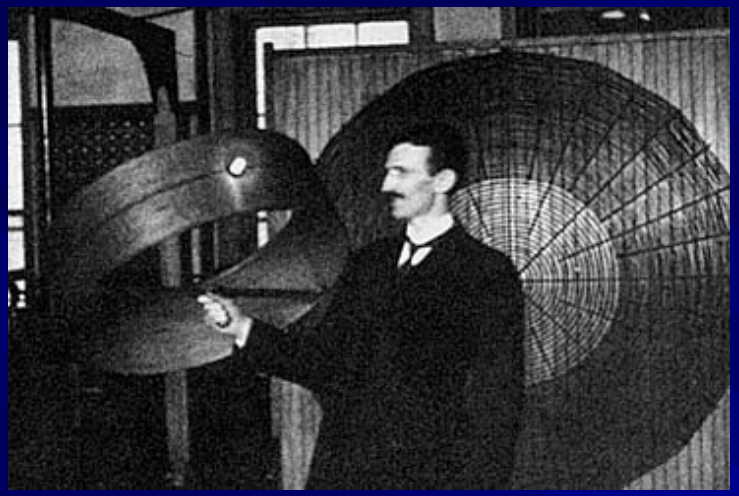


First photograph exposed by phosphorescent light, taken of Tesla in his laboratory

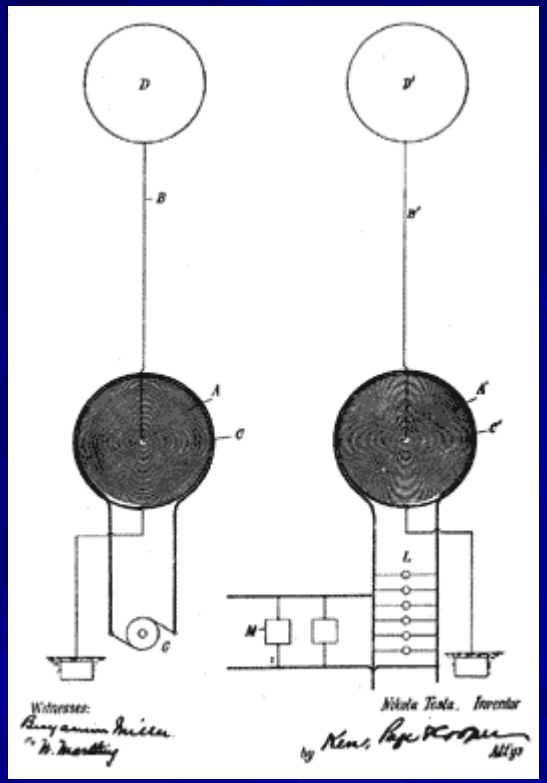


Mark Twain in Tesla's laboratory at 35 South Fifth Avenue, 1895

Wireless Transmission



Tesla demonstrates "wireless" power transmission in his Houston Street laboratory in March 1899.



U.S. patent number 649,621, still the fundamental means for transmitting and receiving radio waves

N Tesla
Apparatus for Transmission of Electrical Energy.
No 555,190 Patented May, 15 1900

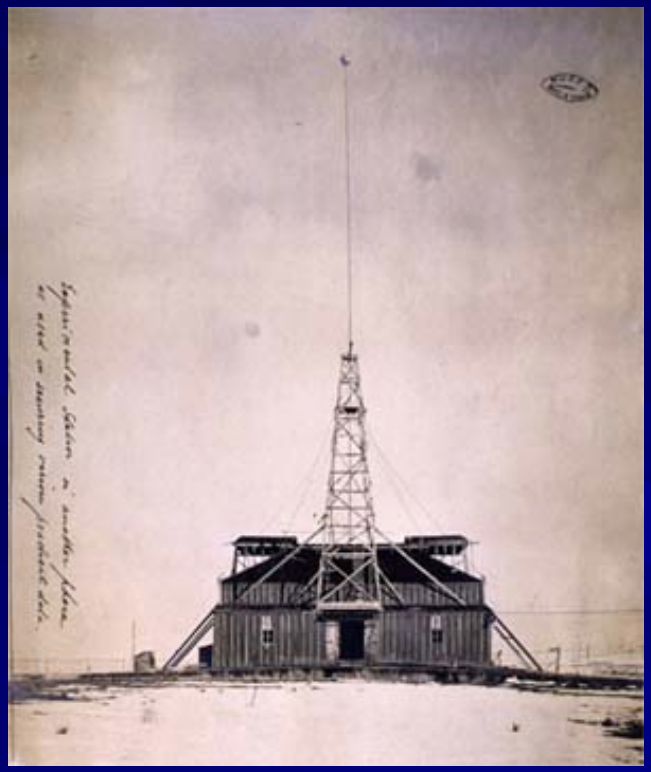
Who really invented radio – Marconi or Tesla??

In 1904, the U.S. Patent Office suddenly and surprisingly reversed its previous decisions and gave Marconi a patent for the invention of radio.

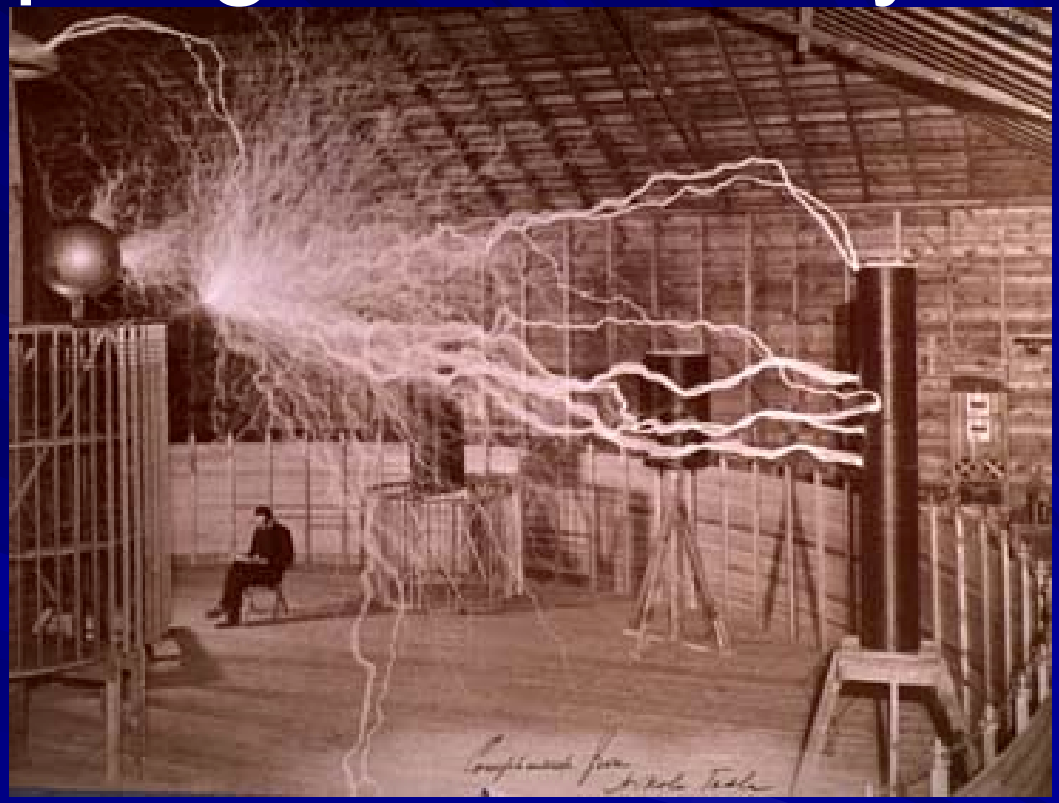
Tesla was furious. He sued the Marconi Company for infringement in 1915, but was in no financial condition to litigate a case against a major corporation.

It wasn't until 1943—a few months after Tesla's death— that the U.S. Supreme Court upheld Tesla's radio patent number 645,576.

Colorado Springs Laboratory

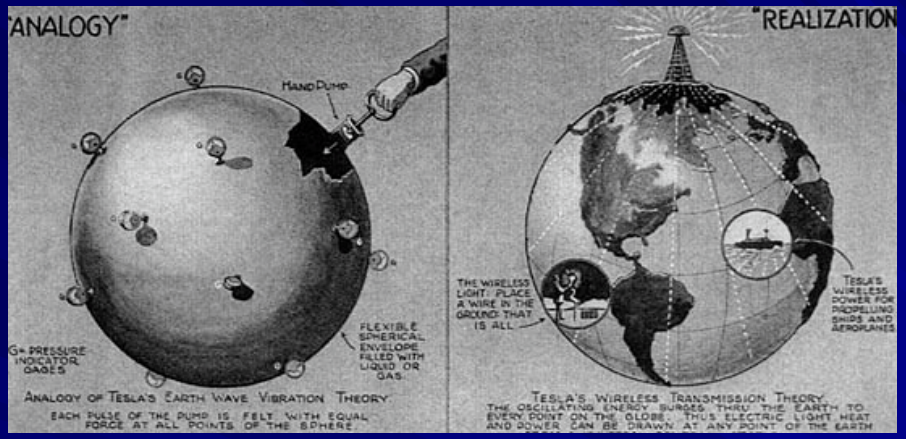


Tesla's experimental station



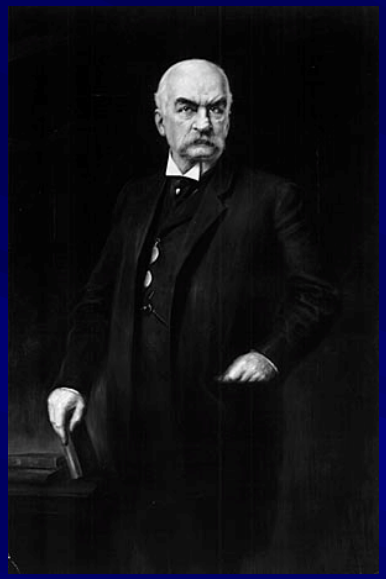
This publicity photo taken at Colorado Springs was a double exposure. Tesla posed with his "magnifying transmitter" capable of producing millions of volts of electricity. The discharge shown is twenty-two feet in length.

Much Mystery to this Day!!!



Caption in *Century Magazine*, June 1900, reads: "The photograph shows three ordinary incandescent lamps lighted to full candle-power by currents induced in a local loop consisting of a single wire forming a square of fifty feet each side, which includes the lamps, and which is at a distance of one hundred feet from the primary circuit energized by the oscillator."

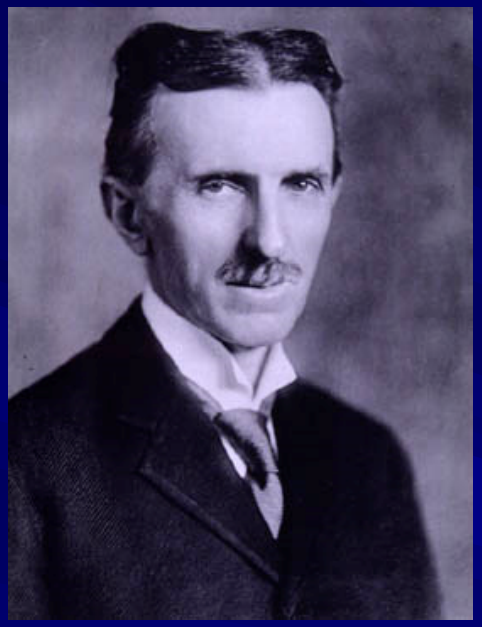
Tesla back to NY



Wall Street financier,
J. Pierpont Morgan

Tesla's tower with dome frame, completed in 1904.

Tesla in Later Years



Portrait photograph of Nikola Tesla in 1920 at age sixty-four.

Tesla's favorite "white dove."

Tesla at a press conference at the Hotel New Yorker July 10, 1935, his seventy-ninth birthday.

Eccentric Tesla

- Tesla began visiting the local parks more often, rescuing injured pigeons, and often taking them back to his hotel room to nurse them.
- His aversion to germs also heightened as he got older, and he began to wash his hands compulsively and would eat only boiled foods. Once a fly landed on his table, and he made the restaurant at his hotel reset the whole table and bring new food.
- He hated to have photographs taken since he thought that his ideas might someday be able to be drawn from the electromagnetic aura that was surrounding him.
- Tesla spoke out vehemently against the new theories of Albert Einstein, insisting that energy is not contained in matter, but in the space between the particles of an atom.

Tesla and War

Tesla envisioned war in the future as a "mere contest" between machines. This concept was illustrated by Paul Frank and appeared in *Science and Invention*, February 1922.

In 1931 Tesla announced to reporters at a press conference that he was on the verge of discovering an entirely new source of energy.

On 11 July 1934 the headline on the front page of the *New York Times* read, "TESLA, AT 78, BARES NEW 'DEATH BEAM.'"

His death beam bears an uncanny resemblance to the charged-particle beam weapon developed by both the United States and the Soviet Union during the cold war.

Tesla’s Death

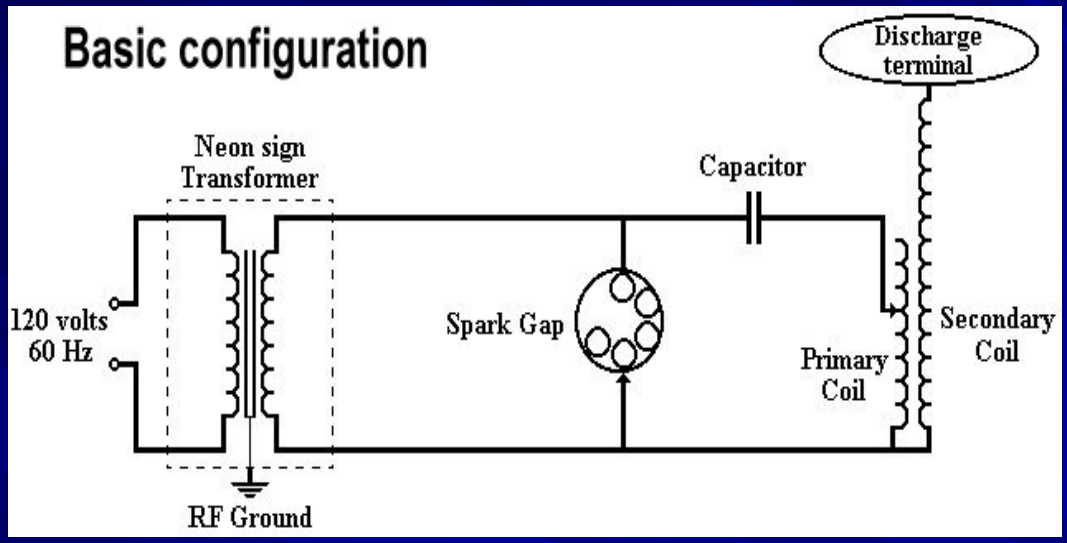
The death mask of Nikola Tesla in the offices of Gernsback Publications, New York City, in celebration of the Tesla centennial, June 25, 1956. The mask was heavily electroplated with copper, a process that took ten days, and was mounted on a marble-composition pedestal. Three medallions, executed in bas-relief on the base, commemorate Tesla's greatest inventions: the Tesla oscillation transformer, the first AC induction motor, and the tower for wireless power transmission.

One of the more controversial topics involving Nikola Tesla is what became of many of his technical and scientific papers after he died in 1943.

Tesla Coil

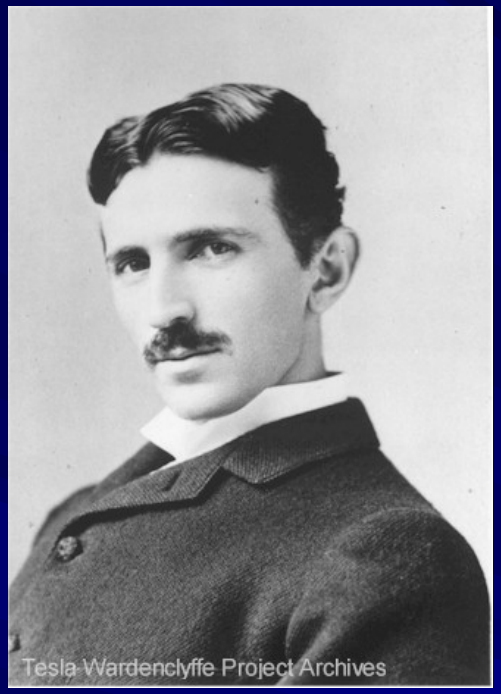
The Tesla coil transforms an input voltage into brief pulses of extremely high voltages. Tesla's largest coil, built at his Colorado Springs lab in 1899, was 52 feet in diameter and generated pulses as high as 12Mv. This invention was patented as part of a high-frequency lighting system.

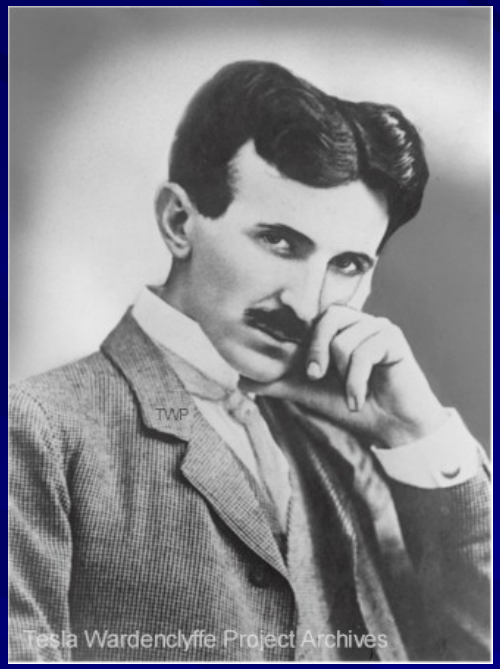
How does a Tesla Coil Work?



Electricity flows into C1 until a high voltage is seen across G1. When this voltage is high enough, a spark jumps across the gap and allows C1 to discharge into L1 and L2. The voltage "bounces" back and forth at an extremely high rate. When the rate of discharge between C1 and L1 matches the rate of C1 and L2, the two circuits are said to be "in resonance" and the voltage goes up through the roof.

This is the current configuration


Tesla Wardenclyffe Project Archives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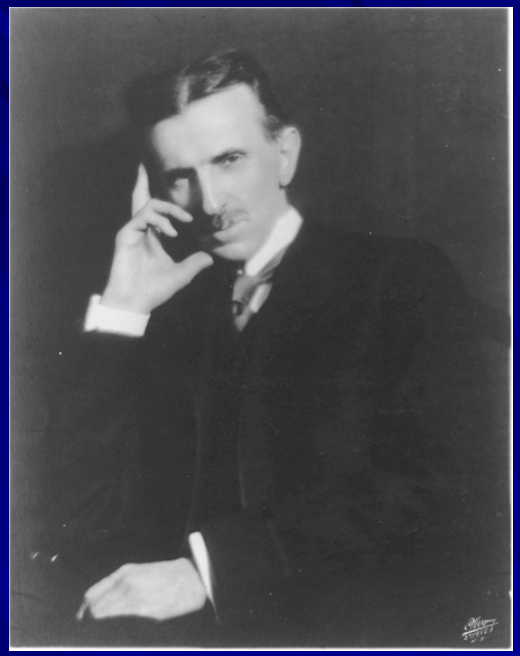

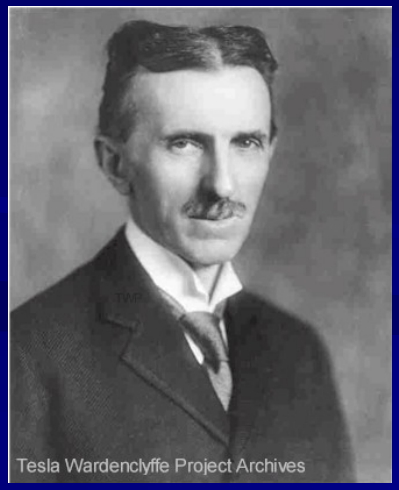
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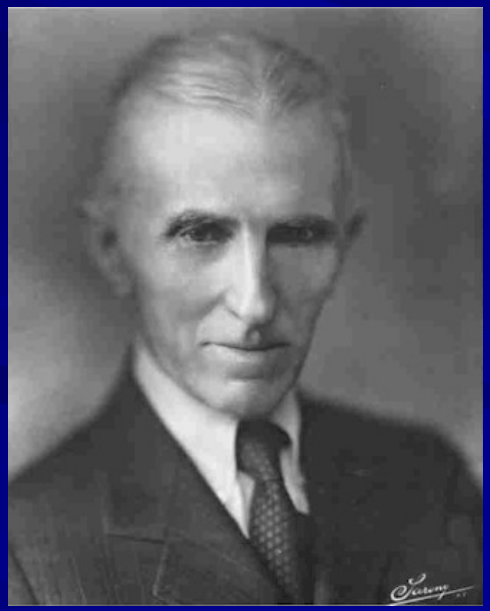

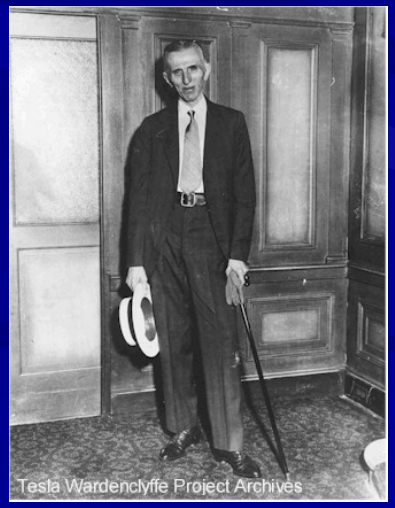
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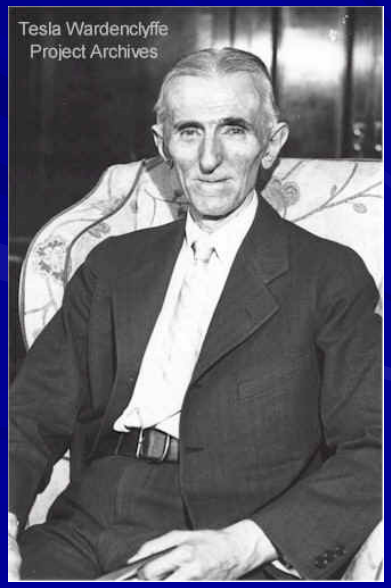
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